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ACCURATE TRANSLATION

TITLE OF THE INVENTION

IMAGE PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

5 The present invention relates to an image  
processing apparatus for joining (restoring  
composition) a plurality of images taken to which one  
composition is divided with an overlap area where  
desired object exists or synthesizing a plurality of  
images taken with a different exposure, and more  
10 particularly to an image processing apparatus for  
extending a viewing angle of a joined image and its  
dynamic range of a synthesized image.

15 In recent years, personal computers (hereinafter  
called PC) got much more capability and their price is  
reducing in accordance with improvement of manufacture  
technique, so that they have been widely used in many  
companies, education, and home.

20 To input images to PC, an image is optically  
picked up from a film photographed by a conventional  
camera and is converted to an image signal to be input.

25 In addition to camera, imaging apparatus such as  
a video camera for taking the image are used in various  
situations. Particularly, in a digital still camera,  
a film, which is used in the general camera, doesn't  
have to be, used. Instead, the image is converted to  
a digital signal and recorded in storage medium, which  
is magnetically or optically recordable, so that

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~~by the movement of the camera so as to join a plurality  
of images obtained by one image pickup element.~~

However, in general when the photographed image is  
subjected to influence of distortion due to the optical  
system, the image is distorted. If the images are  
joined by the technique of Japanese Patent Application  
KOKAI Publication No. 6-141246, the composition of the  
overlapped parts differs between the images, and there  
occurs a problem object is seen double in the join  
image. Also, due to the displacement of the points,  
serving as a reference for joining, the image is  
detected as if it were rotated though the image is not  
actually rotated. As a result, there occurs a problem  
in which the images are not joined well.

To solve the above problems, the applicant of the  
present application proposed an image processing  
apparatus for compensating for influence of distortion  
comprising image correcting means for a geometrical  
correction as described in U.S. Patent <sup>Application Serial No.</sup> 08/541,644  
(filing data: October 10, 1995).

The structure of the image processing apparatus is  
shown in FIG. 18.

In the figure, each of image input sections 1a to  
1c of the image processing apparatus comprises an  
optical system 2, an image pickup section 3 such as CCD,  
and an A/D converter 4. These image input sections are  
arranged to Capture different portions (positions) of

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an object 5 to have the overlapping area.

An output signal of each image pickup section 3 is digitized by the A/D converter 4 so as to be input to each of image correcting sections 17a to 17c. Each of the image correcting sections 17a to 17c reads photographing conditions such as a focus position when a image is taken and a characteristic parameter of the optical system so as to correct the distortion of the images taken by the image input sections 1a to 1c.

10 *ci* Next, in an image joining section 6, the images (serving as input signals), which are corrected by the image correcting sections 17a to 17c, are joined to be a wide-angle image as shown in FIG. 20. Then, the joined image is output to a motor 9, a printer 8 or  
15 ~~a storage medium 9.~~

The image joining section 6 is realized by the structure as shown in FIG. 19.

In this structure, the images a, b, and c are temporarily stored in a frame memory 10 respectively.  
20 Then, an amount of parallel movement S1 and an amount of rotations R1 between the adjacent images (e.g., images a and b) are obtained by a shift detector 11a. Similarly, an amount of parallel movement S2 and an amount of rotations R2 between  
25 the images b and c are obtained by a shift detector 11b.

These amounts of parallel movement S1, S2, and amounts of rotations R1 and R2 are input to

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interpolation calculators 12a and 12b, together with the images read from frame memories 10b, 10c. Thereby, the images whose positional relationship are corrected can be obtained.

5           A coefficient setting device 13 sets coefficients Ca, Cb, and Cc of the respective images of FIG. 20 such that the adjacent images are smoothly joined to each other. The pixel value of each image is multiplied by each of coefficients Ca, Cb, Cc by a  
10 multiplier 14. Then, the overlapping portion is added by an adder 15.

FIG. 20 is a view showing the processing of the overlapping portion of the images to be joined.

15           The image b rotates anticlockwise against the image a. The rotation of the image b and the amount of overlapping (or amount of parallel movement) are calculated by the shift detector 11. Also, as shown in FIG. 20, the pixel value of each image is multiplied by each of coefficients Ca, Cb, Cc so as to smoothly  
20 connect the images a and b, which are overlapped with each other. In this way, the image joining section 6 outputs the image in which the plurality of images are joined with high resolution or a wide viewing angle are provided.

25           Regarding to extend dynamic range of the imaging device, the applicant of the present application proposed the following technique in Japanese Patent

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Application KOKAI Publication No. 63-232591.

Specifically, a plurality of images photographed with different exposure is synthesized so as to generate an image having a dynamic range, which is almost equal to the film.

The above technique can be realized by structuring the image joining section 6 as shown in FIG. 22.

FIG. 22 conceptually explains an example in which two images are synthesized. Even in a case of joining three or more images, the images are synthesized by the same process.

Two images a and b are added to each other at an adder 21 to be stored in the frame memory 10. A linear converting section 22 reads out data of the frame memory 10. The linear converting section 22 calculates values corresponding to R, G, B values of incident light based on a look-up table so as to be input to a matrix circuit 23. The R, G, B values obtained at this time exceed the dynamic range of an input device such as a digital still camera.

The converting table is determined from an exposure ratio,  $R_{exp}$ , of two images by a converting table preparation section. In the matrix circuit 23, a luminance signal value Y is obtained from R, G, B values. A luminance compression section 24 outputs a luminance value Y' which is compressed to adjust to the output device. Then, a ratio of compressed signal

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to original one  $Y'/Y$  is obtained by a divider 25.  
The ratio  $Y'/Y$  is multiplied by outputs R, G, B of the  
linear converting section 22 by a multiplier 25 so as  
to be stored in the frame memory 16 as a joining image  
5 result.

Generally, the signal value to be output from the  
imaging device is saturated for a certain amount of  
incident light in the case of longer time exposure as  
shown in FIG. 21.

10 The value of an additional signal in which the  
signal of the longer exposure and that of the shorter  
exposure are added is changed with respect to the  
amount of incident light as shown by a bent line  
showing as an additional signal in FIG. 21. Then,  
15 a converting table preparation section 27 determines  
a table in which an amount of incident light I is  
estimated from an additional signal value S.

Generally, since the image value is expressed by  
256 steps of 0 to 255, luminance Y of each pixel is  
20 compressed, for example by the following equation (1):

$$Y' = b \cdot Y^a \quad \dots (1)$$

where a is a coefficient for determining a shape of  
compression and b is a coefficient for determining a  
gain of the entire image.

25 If two different exposure images are synthesized  
to each other by the above-mentioned method, there can  
be obtained an image having the dynamic range almost

equal to the film and can be seen well from a dark part to a bright part.

However, in the conventional technique described in U.S. Patent, <sup>Application Serial No.</sup> 08/541,644, photographing conditions, which are necessary for correcting distortion, and the parameter of the optical system have to be set in advance. Due to this, it is difficult to get the image having high resolution image or a wide viewing angle image and a panorama image by simply using an arbitrary photographing device which the user has.

The following will explain about the distortion with reference to FIGS. 23A, 23B, and 23C.

More specifically, the distortion is generally a geometrical deformation, which is caused in accordance with the distance from the center of a lens. If the lattice object is photographed through the optical system without distortion, the image, which is shown in FIG. 23A, can be obtained. However, if the optical system suffered from distortion, the structure, which should be photographed by straight lines, are curved as shown in FIG. 23B. Thus, if the optical system has distortion, a straight line L is curved and captured as a curved line L' (FIG. 23C). As a result, a point Y on the straight line L is moved to a point Y' on the curved line L'. In this case, an amount of distortion  $\Delta R$  at one point on the image can be expressed by a polynomial expression (2):

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$$\Delta R = A1 \cdot R^3 + A2 \cdot R^5 + \dots \quad (2)$$

where R is a distance between a center of the image and the point Y.

To get the image whose distortion is corrected,  
5 point Y' may be moved by only an amount of distortion  $\Delta R$  on the straight line connecting the center C of the image to point Y'. However coefficients A1, A2, ... differ depending on the focal position of the optical system, it is difficult for the general user to know  
10 coefficients A1, A2, ... correctly.

Also, coefficients A1, A2, ... differ depending on the apparatus to be used. Due to this, when the different apparatus is used, the correction coefficient must be adjusted again.

Moreover, if images are taken by different zooming  
15 ratio, the size between adjacent images differs. Due to this, the images cannot be correctly joined to each other though the images are overlapped with each other. Also, for the object close to the user in such a case  
20 of an indoor place, the size is changed even if a photographer moves a few steps.

Moreover, there is a case in which a white balance is automatically adjusted. For example, the color tone differs depending on a case in which the object is  
25 photographed in a direction toward or away from the sun.

Due to this, when the images are joined by the above-mentioned technique, color is smoothly changed

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but the entire image seems unnatural one. Moreover, in the technique of the wide dynamic range, the table for estimating the amount of incident light from the additional signal must be prepared as explained in the prior art. However, as shown in FIG. 21, a point N where the inclination of the additional signal is changed varies depending on the exposure ratio  $R_{exp}$ . For this reason, the user must know the exposure ratio  $R_{exp}$  of the plurality of images to be synthesized in advance. However, in many cases, the digital still cameras on the market have the structure in which the exposure can be adjusted but the user cannot know the ratio exactly.

#### BRIEF SUMMARY OF THE INVENTION

An object of the present invention is to provide an image processing apparatus which can correct images and be joined by a simple operation based on images themselves without knowing coefficients such as distortion of a camera, and an image processing apparatus which can effectively synthesize an image of a wide dynamic range image from only images.

To achieved the above object, there is provided an image processing apparatus comprising:

image input means for dividing one composition to have an overlap area where the same object as each other exists at a joining position to be input as a plurality of image parts;

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correction parameter setting means for setting a correction parameter necessary to correct at least distortion of the plurality of image parts generated in each overlap area or a difference between the image parts;

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image correcting means for correcting at least one image part of the plurality of image parts in accordance with the set correction parameter to eliminate at least distortion of the plurality of image parts generated in each overlap area or the difference between the image parts;

10

image joining means for sequentially joining the plurality of image parts corrected by the image correction means in the overlap area to restore the one composition; and

15

image display means for displaying the plurality of image parts input by the image input means, or at least one image part of the image parts corrected by the image correction means, or the restored image.

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According to the above-structured image processing device, since the image corrected by image correction means can be displayed on the display means to be confirmed, the image can be effectively corrected without knowing the necessary correction parameter, and an image correctly jointed by image joining means can be obtained.

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Also, according to the present invention, there is

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provided

an image processing device comprising:

image input means for inputting one composition as  
a plurality of images photographed at a different  
5 exposure;

correction parameter setting means for setting a  
correction parameter necessary to correct brightness of  
at least one image of the plurality of images having a  
different exposure;

10 brightness correction means for correcting  
brightness of at least one image of the plurality of  
images in accordance with the set correction parameter;

image display means for displaying at least one  
image of the images corrected by the brightness  
15 correction means; and

joining means for estimating an amount of incident  
light obtained when the one input image is input based  
on the plurality of input images and the set correction  
parameter to convert the plurality of images whose  
20 brightness is corrected by the brightness correction  
means to be placed in a displaying range of the image  
display means, thereby joining the plurality of images.

According to the above-structured image processing  
device, the images corrected by the image correction  
25 means are displayed on the image display means to set a  
correction parameter, the images whose brightness is  
corrected by the image joining means to be placed in

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the displaying range of the image display means based on the correction parameter.

The image processing device comprises correction parameter storing means for storing the correction parameters used in correcting the image in connection with names of corrected images or photographing devices and discrimination names of photographing methods. The correction parameter storing means selects a predetermined correction parameter from the correction parameters stored in the correction parameter storing means to be set.

Moreover, the image processing device stores the parameter value once used in the correction in the correction parameter storing means, and the necessary value is selected from the correction parameter storing means. As a result, there is no need of newly correcting the parameter every image from the beginning.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. 1 is a view showing a schematic structure of an image processing device according to a first embodiment of the present invention;

FIG. 2 is a view showing a specific structure of an image correction processing section of FIG. 1:

FIG. 3A is a view showing a view showing instruction of processing to an image displayed on an image display section, and a correcting state of the image;

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FIG. 3B is a view showing instruction of processing to the image displayed on the image display section, and a correction menu;

FIG. 4 is a view showing an example of a type of a  
5 file stored in a correction parameter storing section;

FIG. 5A is a view showing composition of an image to be photographed;

FIG. 5B is a view showing an example of the image photographed by an optical system having  
10 distortion;

FIG. 5C is a view showing composition when joining the images photographed by the optical system having distortion;

FIG. 6 is a showing a schematic structure of an image processing device according to a second  
15 embodiment of the present invention;

FIG. 7 is a view showing the structure of the image correction processing section of FIG. 6;

FIG. 8 is a view showing an example of a  
20 synchronizing result displayed on an image display section of the image correction processing section;

FIG. 9 is a view showing the structure of an image correction processing section in an image processing device according to a third embodiment of the present  
25 invention;

FIG. 10 is a view showing a relationship between a distance from the center of the image and a signal

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FIG. 11 is a view showing the structure of an image correction processing section in an image processing device according to a fourth embodiment of the present invention;

FIG. 13 is a view showing the structure of an image correction processing section having an image expansion/reduction section and a correction parameter setting section;

FIG. 15 is a view showing the structure of an exposure time ratio calculating section;

FIG. 17 is a view showing a display example on the display section of brightness correction;

FIG. 19 is a view showing an example of the structure of an image joining section of FIG. 18;

FIG. 20 is a view showing an overlapping state of

images at a wide angle image joining time to connect the images;

FIG. 21 is a view showing a characteristic of a signal obtained by adding a signal at long time exposure to a signal at short time exposure;

FIG. 22 is a view showing one example of the structure of the image joining section of FIG. 18;

FIG. 23A is a view showing an image having no curve;

FIG. 23B is a view showing an image having distortion; and

FIG. 23C is a view showing a characteristic of the distortion.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of the present invention will now be specifically described with reference to the accompanying drawings.

FIG. 1 shows a schematic structure of an image processing apparatus according to a first embodiment of the present invention. This embodiment shows an apparatus for easily correcting distortion as viewing the display or so to synthesize the corrected images, thereby obtaining an image of high resolution and a wide angle image.

The image processing apparatus of this embodiment comprises a memory card 32, a card reader 33, an image processing section 34, a monitor 7, a printer 8 for a

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print output, and a storage device 9 such as an optical disk storing images, or a memory card.

5 The memory card 32 records image data taken by a digital still camera 31 and a photographing condition data when the image was taken. The card reader 33 reads out image data from the memory card 32. The image processing section 34 reproduces images from those image data, and provides correcting process such as distortion and a white balance to images to be  
10 joined. The monitor 7 displays the joined image and original image data.

The image processing section 34 comprises an image data reproducing section 35, an image correction processing section 36, a signal switching section 37,  
15 and an image joining section 6.

The image data reproducing section 35 provides a processing such as a decompression to image data read by the card reader 33, and reproduces the images and photographing condition data. The image correction  
20 processing section 36 provides correcting process such as distortion and a color tone to the images. The signal switching section 37 executes an image switching for joining the images.

25 Using the apparatus of the above-mentioned structure, a user takes an image to be divided such that parts of an object image are overlapped with each other. In other words, one composition is divided

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to a plurality of image pieces to be taken such that the same object are captured at the end portion.

Processing such as compression, addition of header data is provided to these photographed images (image a, image b, ... ) in the digital still camera 31. Thereafter, these images are recorded to the memory card 32 as image data.

The memory card 32 is inserted to the card reader 33, and recorded image data is read out from the memory card 32 to be fetched to the image processing section 34. Fetched image data is input to the image data reproducing section 35, and processing such as decompression is provided thereto so that image data is reproduced. Then, the image correction processing section 36 provides a correcting process, and corrected image data is input to the image joining section 6. The image joining section 6 has the structure as shown in FIG. 19. The image joining section 6 provides the same processing as described in U.S. Patent <sup>Application Serial No.</sup> 08/045,038 to join the images. The joined image is output to the monitor 7, the printer 8, or the storage medium 9.

FIG. 2 explains the specific structure of the image correction processing section 36.

The image correction processing section 36 comprises an image display section 44, a distortion correction processing section 41, a correction parameter storage section 42, and a correction

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parameter setting section 43.

The image display section 44 displays an original image and a corrected image. The distortion correction processing section 41 provides a distortion to the input image. The correction parameter storage section 42 stores the parameter, which is used in the correcting process due to the distortion correction processing section 41. The correction parameter setting section 43 adjusts the correction parameter to be set by the user's operation. Or, the correction parameter setting section 43 selects the correction parameter read out from the correction parameter storage section 42 to be set.

The image correction processing section 36 differently works depending on the case. There are two cases, one case is that a distortion correction is provided to images taken by a certain camera in which distortion correction is never provided to its images, which is used for the first time. The other case is that the correction is provided to images taken with a camera in which distortion correction has been already provided to its images and correction history has been left.

First, the following will explain the case in which the distortion correction has not been provided to the images taken by a camera.

The distortion correction processing section 41

As  
B2

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B2

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B

~~inputs an image (e.g., image a) having distortion as~~  
shown in FIG. 23B. Then, the distortion correction  
processing section 41 outputs the image corrected based  
on equation (2) to the image display section 44 by use  
of an initial value, set in advance, of coefficients  $A_1$ ,  
 $A_2$ , ... in equation (2). The image display section 44  
simultaneously displays the corrected image and an  
original image a.

Then, when a desired coefficient is set by the  
user's operation, the correction parameter setting  
section 43, which comprises a mechanism for adjusting  
coefficients  $A_1$ ,  $A_2$ , ..., feeds back new coefficients  $A_1$ ,  
 $A_2$ , ... to the distortion correction processing section  
41 to renew the coefficients immediately.

The distortion correction processing section 41 outputs  
the image corrected by the new coefficient set, and the  
image display section 44 changes the displayed image to  
an image newly corrected.

The user operates the correction parameter setting  
section 43 as viewing at least one of two images.  
Thereby, coefficients  $A_1$ ,  $A_2$ , ..., which are used for  
appropriately correcting the image, are determined.  
At this time, to make the user operates easily, the  
correction parameter setting section 43 is preferably  
structured such that an imaginary adjusting knob  
displayed on the display section 44 is operated by a  
mouse, and a keyboard as shown in FIG. 3A. If the

coefficients (A1, A2 in FIGS. 3A, 3B) are changed by the operation of the knob, the "image after correction" on the screen is recorrected in accordance with the new coefficient value, so that the image is renewed. If  
5 two or more images are needed to be displayed on the display screen, an arbitrary number of images can be, of course, displayed.

When the user judges that the correction is sufficient, he/she presses an "OK" key (clicks in  
10 the case of the mouse) to determine the coefficients A1, A2, ... Thus, the determined coefficients are stored in the correction parameter storage section 42 together with names identifying cameras, which are arbitrarily added by the user. For example, they may be stored to  
15 the correction parameter storage section 42 as a file as shown in FIG. 4.

Arbitrary images can be used for adjustment of the coefficients. However, the image which includes  
20 abject with straight lines such as a building, a book shelf, a window frame, and graph paper, can be easily adjusted.

Next, the following will explain for the case of correcting images by the camera in which its images has been already corrected in the past and the  
25 coefficients A1, A2, ... by that time are stored in the parameter storage section 42 as a file.

In this case, since the correction parameters are

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stored with names of photographing equipments, those data is read when the image processing device is started, and displayed on the image display section 44 in a menu form as shown in FIG. 3B. If the user  
5 selects the name of the device to be used from the menu screen, the corresponding coefficients  $A_1$ ,  $A_2$ , ... are read out to the distortion correction processing section 41 from the correction parameter storage section 42 through the correction parameter setting  
10 section 43. Thereby, the image to which the distortion correction processing is provided is output from the distortion correction processing section 41.

As explained above, according to this embodiment, it is unnecessary to know distortion data of the  
15 optical system of photographing devices in advance. In other words, the user can determine the correction coefficients as viewing only the image itself. As a result, even in the case of the camera which is used for the first time, there is no need of knowing the  
20 characteristic of the optical system in advance.

Also, in the case of using the camera in which the photographed images were corrected in the past, the correction coefficients of distortion are recorded as data. As a result, the correction processing can be  
25 executed by only selecting data from the menu. Therefore, it is possible to avoid the complication of the operation in which the parameter must be set every

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time to correct the entire images used in the image synchronization.

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In this embodiment, there was used the digital still camera in which the images are stored in the memory card. However, the present invention is not limited to the digital still camera. The image processing may be executed even by a device in which data is directly input to the image reproducing section. Moreover, the above embodiment explained the case in which the plurality of images was photographed by one input device. However, the images can be photographed by the structure using a plurality of input devices simultaneously. Furthermore, though this embodiment explained that the correction parameter setting section 43 was the imaginary adjusting knob on the image display section 44, another switch of a rotation type or a slide type may be used.

Moreover, this embodiment explained the structure in which the image was corrected as comparing the original image with the processing result. However, in the case of the image of the object which includes straight line structure such as a building, a book shelf, a window frame, etc., only the image after the correction processing is displayed on the image display section 44, and the lines are adjusted to be straight. Thereby, the coefficients  $A_1$ ,  $A_2$  can be determined.

The following will explain the image processing

device of a second embodiment.

This embodiment, which is a modification of the first embodiment, will be explained with reference to FIGS. 5 to 8. In these figures, the same reference numerals are added to the same structural portions as  
5 FIGS. 1 and 2, and the explanation is omitted.

FIG. 6 is a view showing the structure of this embodiment. The second embodiment is different from the first embodiment in the point that the joined image  
10 output from the image joining section 6 is input to the image correction processing section 36. FIG. 7 shows the structure of the image correction processing section 36. FIG. 8 shows one example of the image displayed on the image display section 44 of the image  
15 correction processing section 36.

According to this structure, image data (image a) to which decompression is provided by the image data reproducing section 35 is input to the distortion  
20 correction processing section 41 so that data, which is corrected by correction parameter values A1, A2, ... set in advance, is output to the image joining section 6. Similarly, the images, which are adjacent to the corrected image, are corrected by the distortion  
25 correction processing section to be output. The output images are joined by the image joining section 6, so that the joined image is generated. Then, the resultant image is input to the image correction

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processing section 36, and displayed by the image display section 44.

Next, the following will explain an example of the actual processing by the user's operation with reference to FIGS. 5A, 5B, and 5C.

FIG. 5A is an object to be photographed. When composition of the object is divided and input through the optical system having distortion to have an overlap area where the same object as each other exists at a joining position as a plurality of image parts.

For example, a plurality of pairs of characteristic points (P1 and P1', P2 and P2', and P3 and P3' in FIG. 3B) are set on the image. This setting can be automatically executed by the image joining section 6 under control of a predetermined program. Or, this setting can be designated by the user's operation. Two points are selected from the pair of characteristic points. The following will explain the case in which P1 and P2 are selected.

At this time, it is assumed that an amount of parallel movement and an amount of rotation are obtained on the basis of P1 and P2 and the images are joined by the image joining section 6 as the distortion correction coefficients A1, A2, ... are maintained incorrectly as they are. As a result, as shown in FIG. 5C, P1 and P1' are correctly conformed to each other. Also, P2 and P2' are correctly conformed to

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each other. However, P3 and P3' are not conformed to each other. Then, the other points of its surroundings are not conformed to each other.

At this time, the joined result is displayed on the image display section 44, and the user adjusts the coefficients A1, A2, ... such that points other than reference points P1 and P2 are conformed to each other as viewing the display by the image processing device shown in FIG. 6. The adjusted coefficients A1, A2, ... are immediately input to the distortion correction processing section 41. Then, the newly corrected images are joined to each other by the image joining section 6, and displayed on the image display section 44 again.

At this time, if the coefficients A1, A2, ... are correctly set, not only P1 and P1', P2 and P2' but also P3 and P3' are conformed to each other, simultaneously. By this method, the image whose distortion is seemingly unclear such as a landscape image, and a figure image can be easily corrected.

In the above embodiment, the user adjusted the coefficients A1, A2, ... as viewing the images displayed on the image display section 44. However, a shift between P3 and P3' is automatically detected, and the coefficients A1, A2, ... may be automatically corrected such that the detected shift becomes 0 or minimum.

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Next, FIG. 9 shows the structure of the image correction processing section of the image processing device of a third embodiment.

5 In these figures, the same reference numerals are added to the same structural portions as the first and second embodiments, and the explanation is omitted.

Generally, due to influence of peripheral reduction light in the optical system such as a camera, the brightness of the images is reduced as the image advances to the periphery. As a result, when the images with the peripheral reduction light are joined to each other, the image becomes dark at the overlapping area, and an unnatural joining image is generated.

15 The peripheral reduction light is a phenomenon in which the brightness of the image becomes darker as a distance R from the center of the image is increased as shown in FIG. 10. A ratio of signal value S' to an ideal signal value with the peripheral reduction light can be approximately obtained by the following polynomial expression (3):

$$S'/S = B_0 + B_1 \cdot R + B_2 \cdot R^2 + \dots \quad (3)$$

25 In this case, the image correction processing section 36 comprises the image display section 44, a peripheral reduction light correction processing section 46, a peripheral reduction light correction parameter storage section 47, and a peripheral

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reduction light correction parameter setting selection section 48.

In the peripheral reduction light correction parameter setting selection section 48, an imaginary knob for displaying coefficients  $B_0, B_1, B_2, \dots$  is moved to set such that brightness of the image center and that of the surroundings are the same.

If the coefficients  $B_0, B_1, B_2, \dots$  are set by the above-mentioned structure, the image can be easily corrected based on the image itself even if the user does not know various parameters of the optical system of a camera. As a result, the images joined by the image joining section 6 does not become dark even at the overlapping portion, and a natural image can be obtained as an entire screen.

Same as the case of distortion, the marginal is the phenomenon peculiar to its optical system of the imaging apparatus. As explained in the first embodiment, the correcting coefficient values are once stored in accordance with names of photographing devices. Then, the images can be corrected by selecting the name from the menu at the second time and the following.

Moreover, this embodiment explained that the images were corrected as comparing the original image with the process result. However, since the brightness of the entire image may be uniformed, only the image

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after correction is displayed on the image display section 44, and the coefficients B0, B1, B2, 1 may be set and selected.

5       Next, the following will explain the structure for correcting a color tone by the image processing apparatus of a fourth embodiment of the present invention with reference to FIGS. 11 and 12.

10       The image processing correction processing section 36 in FIG. 11 comprises the image display section 44, a color tone correcting section 51, and the correction parameter setting section 43.

15       The color tone correcting section 51 converts the original image to hue (H), saturation (S), and intensity (I), respectively by HIS transformation. The correction parameter setting section 43 adjusts the correction parameter for transformation to H, S, I so as to correct the color tone.

20       The color correction section 51 corrects the input image based on hue H, saturation S, and intensity I to be output to the image display section 44. The user operates the knob for adjusting hue H, saturation S, and intensity I on the screen shown in FIG. 12 as comparing the images displayed on the image display section 44, in order that both images have the same color tone.

25

By the above-structured image correction processing device 36, not only the color tone of the

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overlapping area where the adjacent images are joined but also the color tone of the overall of the image can become natural. This embodiment explained that the original image was converted to hue (H), saturation (S), and intensity (I), respectively. However, similar to the adjustment of white balance, signal levels of R, G, B can be adjusted.

Moreover, as shown in FIG. 13, an image magnification/reduction section 52 and the correction parameter setting selection section 43 are provided to the image correction processing section 36. Thereby, there can be obtained a well joined image in accordance with the difference in a zoom ratio, and the change of the object size due to the change of the photographer's position.

Next, the following will explain the structure to extend the dynamic range of the input image by the image processing apparatus of a fifth embodiment of the present invention with reference to FIGS. 14 to 17.

The image processing apparatus of this embodiment calculates exposure ratio  $R_{exp}$  from the taken image, and synthesizes images with the calculated exposure time ratio. In these figures, the same reference numerals are added to the same structural portions as the first embodiment, and the explanation is omitted.

The image processing apparatus of this embodiment has the structure in which an exposure time ratio

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calculating section 61 is provided to the image processing section 34.

5 In the image processing section 34, reproduced images a and b are input to the exposure time ratio calculating section 61 through the signal switching section 37. As a result, an exposure time ratio  $R_{exp}$  is input to the image joining section 6. In the image joining section 6, the images a and b are synthesized with the calculated exposure time ratio  $R_{exp}$ , and the  
10 output image exceeds the dynamic range of the input device. Since the structure of the image joining section 6 uses the structure same as FIG. 22, the explanation is omitted.

15 FIG. 15 explains the structure of the exposure time ratio calculating section 61.

The exposure time ratio calculating section 61 comprises the image display section 44, an exposure time ratio setting section 63 for adjusting the exposure time ratio  $R_{exp}$  by the user, and a brightness  
20 correcting section 62 for correcting brightness of the input image based on the exposure time ratio  $R_{exp}$  set by the exposure time ratio setting section 63.

FIG. 16 is a view showing the processing by the brightness correcting section 62. The signal  $S_{out}$ ,  
25 which is obtained by correcting the image signal  $S_{in}$ , can be expressed by the following equation (4):

$$S_{out} = R_{exp} \cdot S_{in} \quad \dots (4)$$

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At this time, if  $R_{exp} > 1.0$ , the image becomes brighten. If  $R_{exp} < 1.0$ , the image becomes darker.

FIG. 17 shows a display example on the display section.

5           In the image a, which is used as a reference image, the indoor portion where a table, a flower, etc are presented is captured at a suitable exposure. Then, the portion out of the window where woods and mountains can be seen is captured at an over-exposure. In the  
10       image b, which is used as an adjusting image, the portion out of the window is formed at the suitable exposure, and the indoor portion is formed at the under-exposure.

          The image a is displayed as a reference image, and  
15       the knob displayed on the screen is adjusted to correct brightness of the image b. The user designates the end of adjustment with an "OK" key when the brightness of the entire image b reaches the same as the reference image (image a). The exposure time ratio  $R_{exp}$  set in  
20       this way is output to the image joining section 6, and the processing of the wide dynamic range is executed.

          According to this embodiment, since the user can obtain exposure time ratio  $R_{exp}$  as confirming the image, a desired device can be used in the input device for  
25       inputting the image. Also, since it is unnecessary to record exposure time when taking images, the processing of the wide dynamic range can be easily executed.

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Moreover, this embodiment explained the example in which the exposure time ratio between two images was used as a correction parameter. However, the present invention is not limited to the above example. The exposure time ratio among three or more images can be used as a correction parameter. The embodiment explained that one image was used as a reference image and the brightness of only the other image was corrected. However, brightness of both images can be corrected to generate an image having intermediate brightness. At this time, the exposure time ratio can be shown as in FIG. 16.

Moreover, as a method for photographing a plurality of brighter and darker images having a different exposure, the diaphragm of the camera can be changed, and the amount of incident light may be controlled by transmittance of the reduction light filter. In other words, as the correction parameter, which is necessary for the processing of the wide dynamic range, the parameter, which shows the exposure ratio among the plurality of images, may be used. For example, the exposure time ratio shown in the above embodiment, a diaphragm ratio, a transmittance ratio of the reduction light filter can be used as a correction parameter.

In the above-explained embodiments, the images are taken by the digital still camera. However, the same

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processing as in the embodiments can be executed even  
in the image, which is obtained by digitizing the film  
photographed by the conventional camera, or the image,  
which is input from the image photographed by the video  
5 camera or the digital video camera through an image  
input board. The monitor 7, which outputs the joined  
image, can be used as the image display device 44 of  
each embodiment.

Moreover, the above-explained embodiments can be  
10 combined with each other. Particularly, the correction  
parameter storage section 42 can be combined with the  
structure described in the first to third embodiments.  
In this case, the correction parameter storage  
section 42 can store the parameter if the user knows  
15 the characteristic of the optical system. Also, the  
correction parameter storage section 42 can be combined  
with the structure described in the fourth and fifth  
embodiments. In this case, the correction parameter  
storage section 42 can store the parameter to be used  
20 as a default value when the user executes the  
adjustment.

According to the present invention, there can be  
provided the image processing apparatus, which can  
correct only from the image photographed by a various  
25 imaging apparatus which the user has or the  
photographing device of a reasonable price, thereby  
obtaining the joined images with wide viewing angle and

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the image of the wide dynamic range. In this case,  
there is no need of knowing the characteristics of the  
distortion and peripheral reduction light optical  
system in advance. Moreover, there is no need of using  
5 the photographing device of a high price, which can  
control and record the photographing conditions such as  
exposure time, white balance, etc.

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